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RESEARCH MEMORANDUM

FLIGHT INVESTIGATIONS AT HIGH-SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS TO DETERMINE ZERO-LIFT DRAG OF FIN-STABILIZED BODIES OF REVOLUTION HAVING FINENESS RATIOS OF 12.5, 8.91, AND 6.04 AND VARYING POSITIONS OF MAXIMUM DIAMETER

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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FLIGHT INVESTIGATIONS AT HIGH-SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS TO DETERMINE ZERO-LIFT DRAG OF FIN-STABILIZED BODIES OF REVOLUTION HAVING FINENESS RATIOS OF 12.5, 8.91, AND 6.04 AND VARYING POSITIONS OF MAXIMUM DIAMETER

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SUMMARY

Rocket-powered models were flown at high-subsonic, transonic, and supersonic speeds to determine the zero-lift drag of fin-stabilized parabolic bodies of revolution differing in fineness ratio and in position of maximum diameter. The present paper presents the results for fineness ratio 12.5, 8.91 and 6.04 bodies having maximum diameters located at stations of 20, 40, 60, and 80 percent of body length. All configurations had cut-off sterns and all had equal base, frontal, and exposed fin areas.

For most of the supersonic-speed range models having their maximum diameters at the 60-percent station gave the lowest values of drag coefficient. At supersonic speeds, increasing the fineness ratio generally reduced the drag coefficient for a given position of maximum diameter.

INTRODUCTION

In order to investigate the phenomena of the fuselage-drag rise associated with transonic and supersonic speeds, the NACA is conducting a series of flight tests on bodies of revolution differing in fineness ratio and in position of maximum diameter. The body profiles have been chosen so as to represent the practical range of shapes of transonic and supersonic aircraft. The tests are conducted at the Langley Pilotless Aircraft Research Station, Wallops Island, Va. by means of rocket-propelled models. The first part of the investigation is

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presented in reference 1 where a comparison was made of experimental and theoretical drag values for fin-stabilized parabolic bodies of revolution with fineness ratio 6.04 having maximum-diameter stations at 20, 40, and 60 percent of the body length. The present paper is a presentation of drag data obtained for comparable bodies of fineness ratio 12.5 and 8.91 having maximum-diameter stations at 20, 40, 60, and 80 percent of the body length.

In order to summarize the results obtained to date, the results of reference 1 are included, together with an additional configuration having fineness ratio 6.04 and maximum-diameter station at 80 percent. The lack of pressure and fin drag data for the configurations of these tests precludes a comprehensive analysis of the present results. However, an investigation is being undertaken to isolate the effect of the fins and to determine surface and base pressures for some of the present configurations.

SYMBOLS

a,b	body-shape parameters in equations (1) and (2), inches^{-1}
C_D	total-drag coefficient based on body frontal area
F.R.	fineness ratio (L/D)
L	length of body, inches
D	maximum diameter of body, 7.5 inches
K	position of maximum diameter (l/L)
l	station at maximum diameter, inches
M	Mach number
R	Reynolds number based on body length
d	body diameter at station x, inches
x	variable distance along body axis from nose, inches

MODELS AND TESTS

The general arrangement of the test configurations is shown in figures 1, 2, and 3 and photographs of the test vehicles are shown in figures 4, 5, and 6. The profiles of the bodies describe parabolic arcs, the equations of which are as follows

$$0 < x < KL \qquad d = D - 2a(KL - x)^2 \tag{1}$$

$$KL < x < L \qquad d = D - 2b(KL - x)^2 \tag{2}$$

The body-shape parameters, a and b, have the values given below

Configuration	Fineness ratio	K	a	b
1	12.5	0.20	0.010673	0.000375
2	12.5	.40	.002668	.000667
3	12.5	.60	.001186	.001501
4	12.5	.80	.000667	.006006
5	8.91	.20	.021004	.000739
6	8.91	.40	.005251	.001313
7	8.91	.60	.002334	.002954
8	8.91	.80	.001313	.011818
[a]9	6.04	.20	.04564	.00161
[a]10	6.04	.40	.01141	.00285
[a]11	6.04	.60	.00507	.00642
12	6.04	.80	.00285	.02563

[a]Configuration taken from reference 1.

For all models the frontal area $(\pi D^2/4)$ was 0.307 square foot, the base area was 0.0586 square foot, and the exposed fin area was 1.69 square feet. The lengths of the bodies were 93.72 inches for fineness ratio 12.5, 66.81 inches for fineness ratio 8.91, and 45.32 inches for fineness ratio 6.04. A close examination of the test body shapes will reveal that some of the configurations had almost identical noses and that other configurations had almost identical afterbodies.

All test bodies were of wood finished with clear lacquer to form a smooth and fair surface.

All models were stabilized by three 45° sweptback fins of 1.69 square feet total exposed area. The dural fins were of 0.0278 thickness ratio in the streamwise direction and so located that the trailing edge of the fins always intersected the body at the 90.53-percent station. All fins measured 9 inches in the streamwise direction.

A two-stage propulsion system was employed utilizing a 3.25-inch Mk. 7 aircraft-rocket motor as the sustainer unit and a 5-inch HVAR motor as the booster unit. The booster unit was stabilized by four fins and was attached to the sustainer motor by means of a nozzle-plug adapter.

Test data were obtained and reduced by the same methods described in references 1 and 2. Drag coefficients have been based on body frontal area (0.307 square foot) and represent the total drag of the configurations including fin and interference drag.

The flight tests of the three fineness-ratio groups covered a range of body-length Reynolds numbers from 20×10^6 to 85×10^6. In figure 7 the Reynolds number encountered in flight, based on body length, is plotted against Mach number.

RESULTS AND DISCUSSION

In figures 8, 9, and 10 are shown the individual curves of drag coefficient based on frontal area against Mach number for the present test configurations. Past experience with the Doppler technique of drag-data reduction has indicated that the inherent systematic errors are less than random discrepancies between theoretically identical models. Therefore, it is believed that the amount of scatter in the data for models of the same configuration is indicative of the reliability that may be placed upon the results. For the purposes of comparison, the data of figures 8, 9, and 10, along with the fineness ratio 6.04 data of reference 1, are grouped in figure 11 according to fineness ratio and in figure 12 according to position of maximum diameter.

Figure 11 shows that for the fineness ratios tested the 20- and 80-percent locations of maximum diameter gave considerably higher values of C_D at supersonic speeds than did the more central locations. In every case, the 20-percent location was by far the least desirable position tested, while the 60-percent location was the most desirable. At supersonic speeds, the effect of varying the position of maximum diameter becomes more marked with decreasing fineness ratio. At subsonic speeds, decreasing the fineness ratio decreases the effect of varying the position of maximum diameter.

In spite of irregularities in the subsonic data for the fineness ratio 12.5 and 8.91 groups, it may be observed that the optimum location of maximum diameter may be different from that at supersonic speeds. The best example of this lies in the 12.5 fineness ratio group where the present data indicated that the model having its maximum diameter at the 60-percent station had the least drag at supersonic speeds but the greatest drag at subsonic speeds.

Figure 12 shows that at supersonic speeds the value of C_D increases with decreasing fineness ratio but to an extent governed by the position of maximum diameter. Fineness ratio has its largest effect at the 20-percent station. At 40- and 60-percent stations, the effect of fineness ratio is smaller than at 20 or 80 percent. Data for all maximum-diameter stations indicate that the fineness ratio 12.5 group gave the lowest value of C_D at supersonic speeds and the highest at subsonic speeds.

For each fineness ratio the force-break Mach number was lowest for the 20-percent maximum-diameter location. For all the maximum-diameter locations tested the force-break Mach number increased with increasing fineness ratio.

In figure 13 the value of drag coefficient at Mach numbers of 1.20, 1.40, and 1.55 are plotted against the location of maximum diameter, K, for each of the three fineness ratios. This figure shows that for the three Mach numbers and for all fineness ratios, the 60-percent station is near the position for minimum drag coefficient.

CONCLUSIONS

Flight tests were made to determine the zero-lift drag of fin-stabilized parabolic bodies of revolution differing in fineness ratio and in position of maximum diameter. The following effects were noted:

1. At supersonic speeds, the 60-percent location of maximum diameter resulted in the least drag for all positions tested.

2. At supersonic speeds, position of maximum diameter has its greatest effect on drag for bodies of low fineness ratio.

3. For a given position of maximum diameter, the bodies of 12.5 fineness ratio had the least drag at supersonic speeds but the greatest drag at subsonic speeds.

4. For all of the maximum-diameter locations tested, the force-break Mach number increases with increasing fineness ratio.

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REFERENCES

1. Katz, Ellis R.: Flight Investigation at High-Subsonic, Transonic, and Supersonic Speeds to Determine Zero-Lift Drag of Bodies of Revolution Having Fineness Ratio of 6.04 and Varying Positions of Maximum Diameter. NACA RM L9F02, 1949.

2. Katz, Ellis R.: Results of Flight Tests at Supersonic Speeds to Determine the Effect of Body Nose Fineness Ratio on Body and Wing Drag. NACA RM L7B19, 1947.

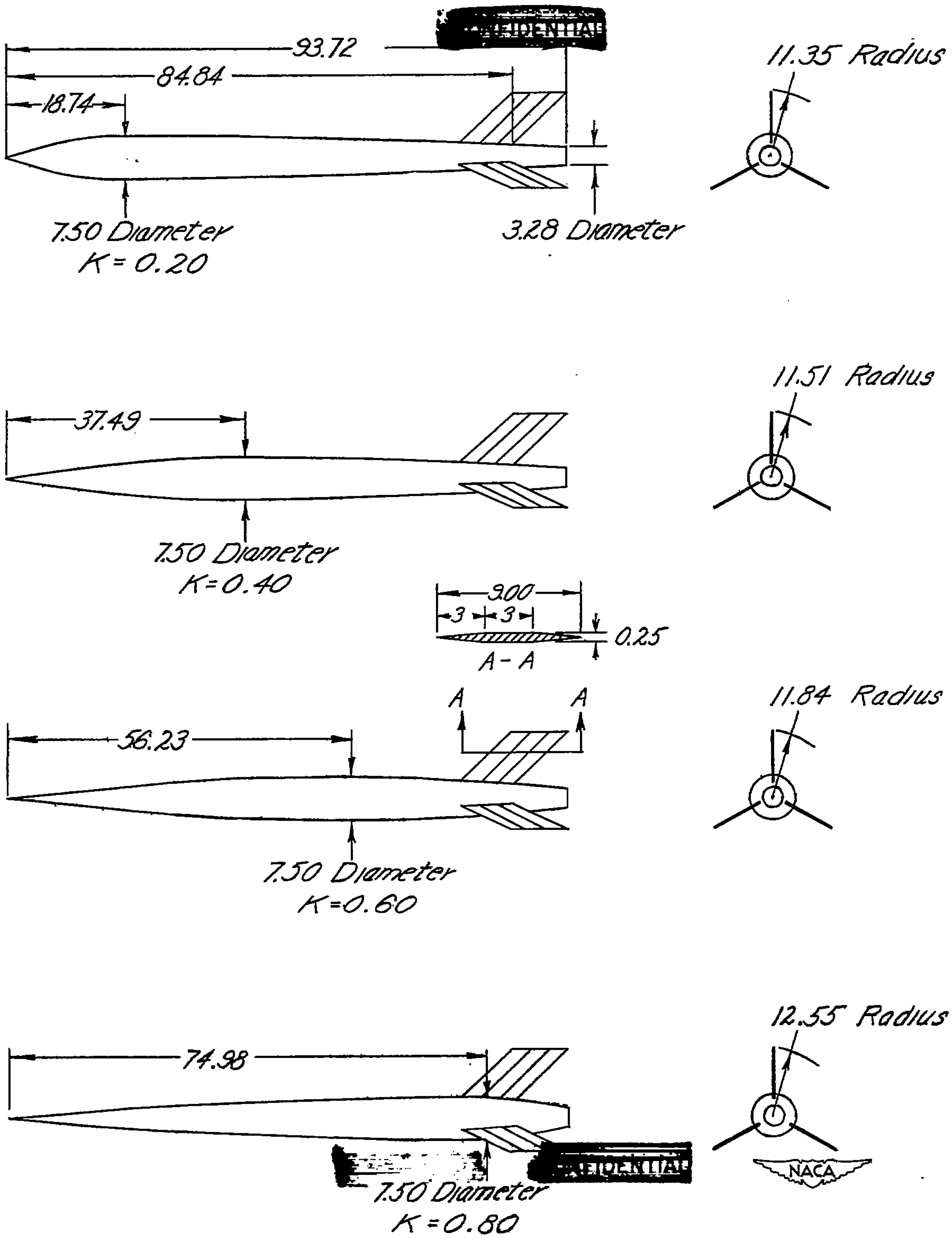

Figure 1.- General view of fineness-ratio-12.50 configurations.

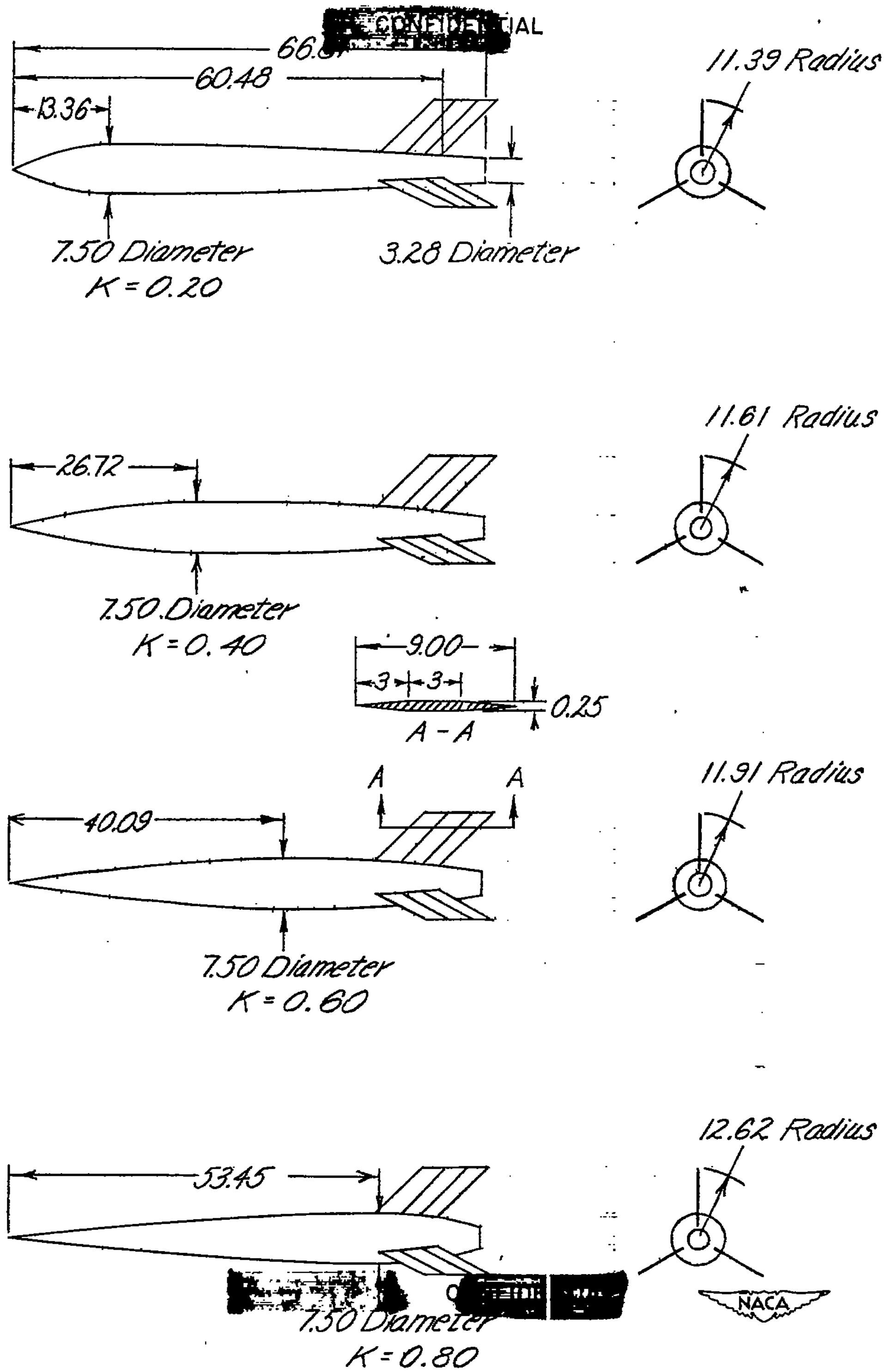

Figure 2.- General view of fineness-ratio-8.91 configurations.

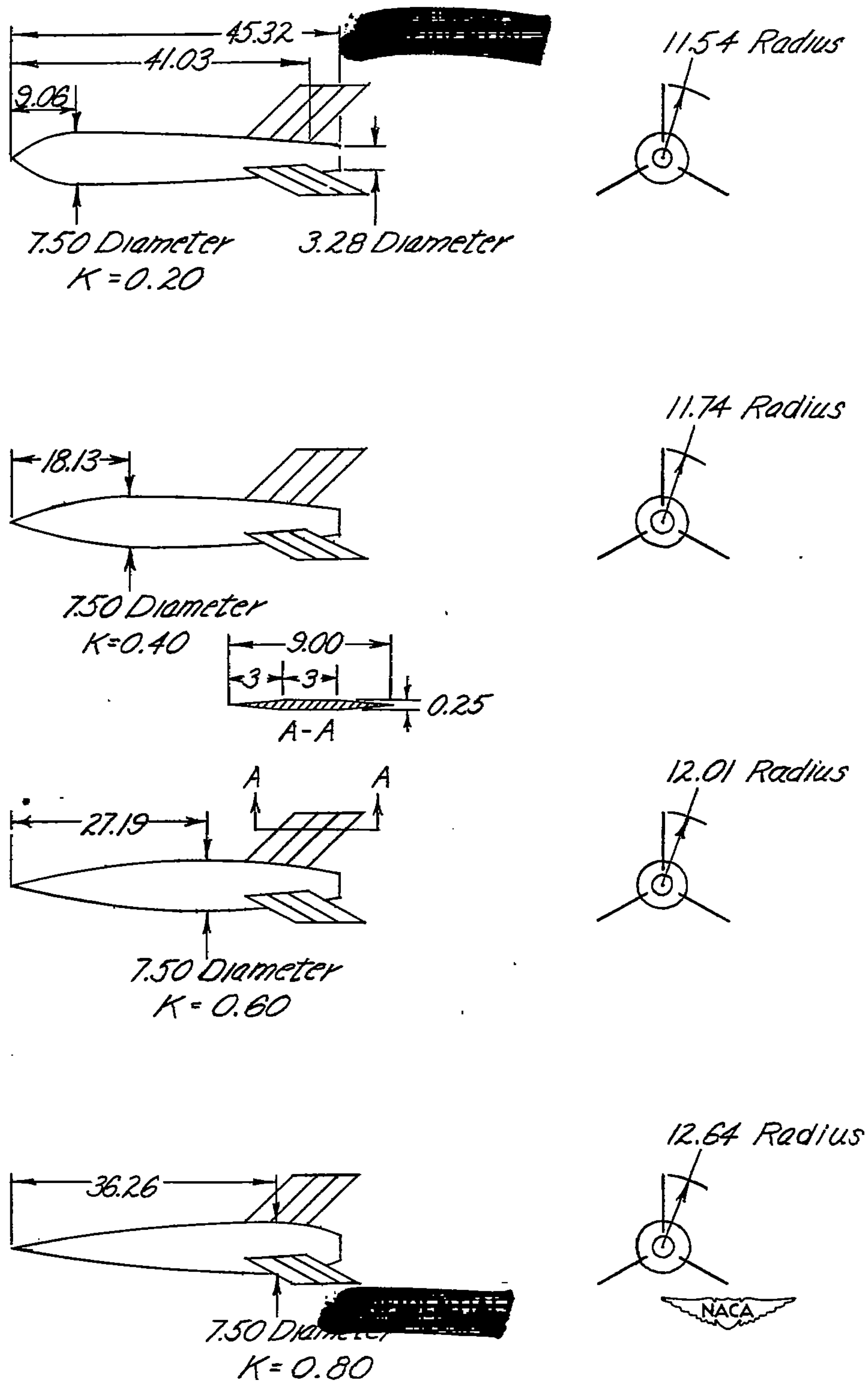

Figure 3.- General view of fineness-ratio-6.04 configurations.

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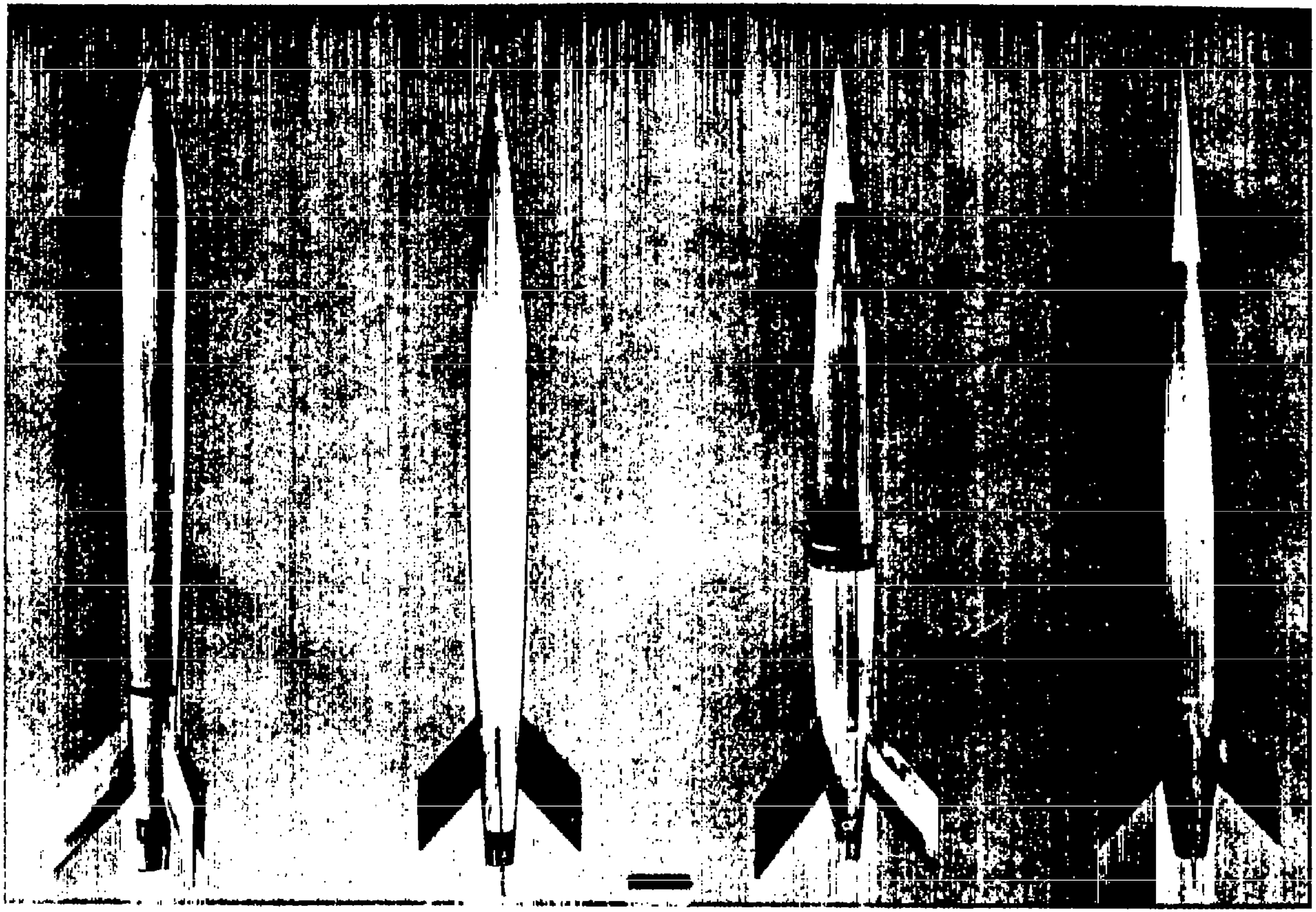

Figure 4[redacted] Fineness-rati[redacted]-12.5 models. L-62109

[redacted]

Figure 5.- Fineness-ratio-8.91 models. L-62107

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[redacted]

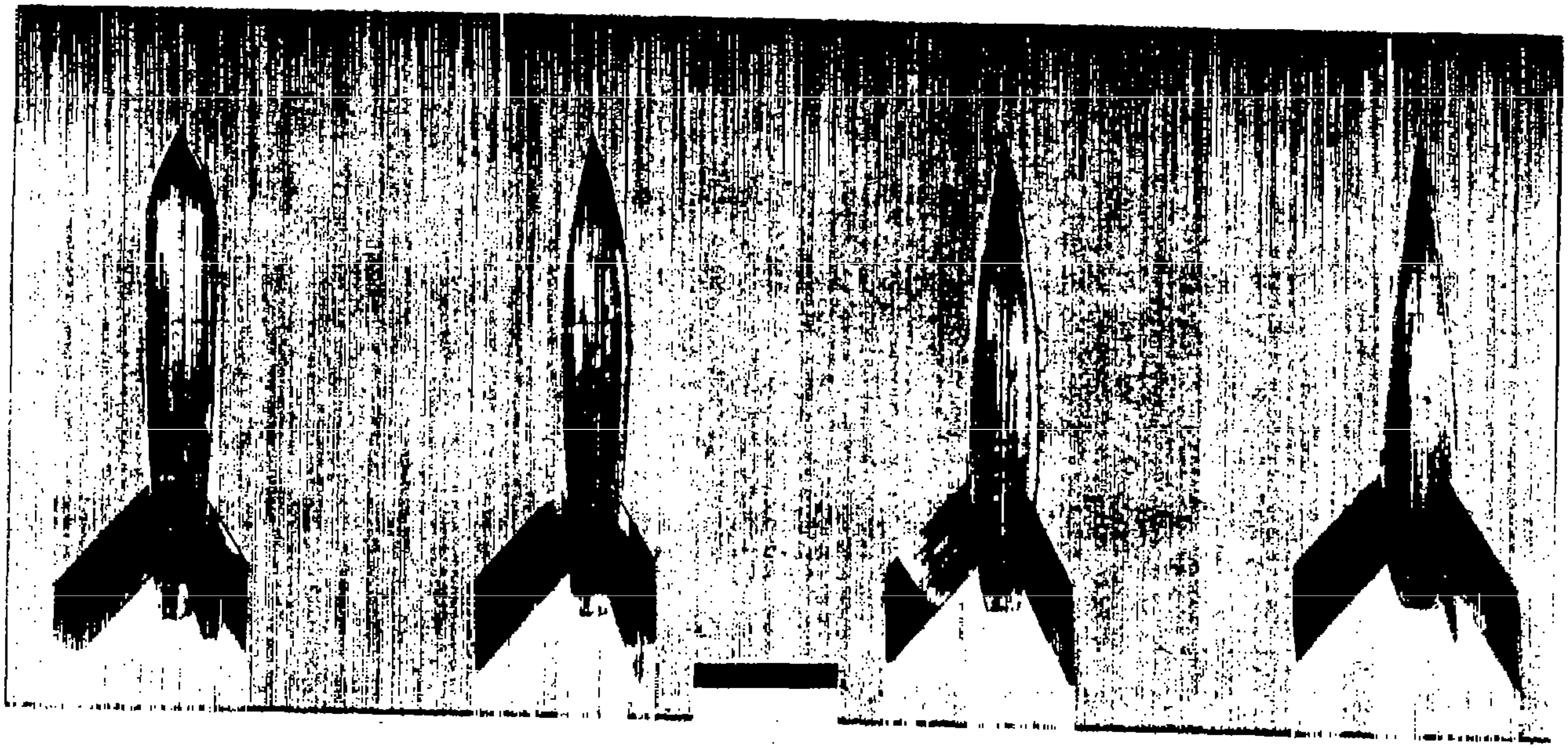

Figure 6.- Fineness-ratio-6.04 models.

L-62108

[redacted]

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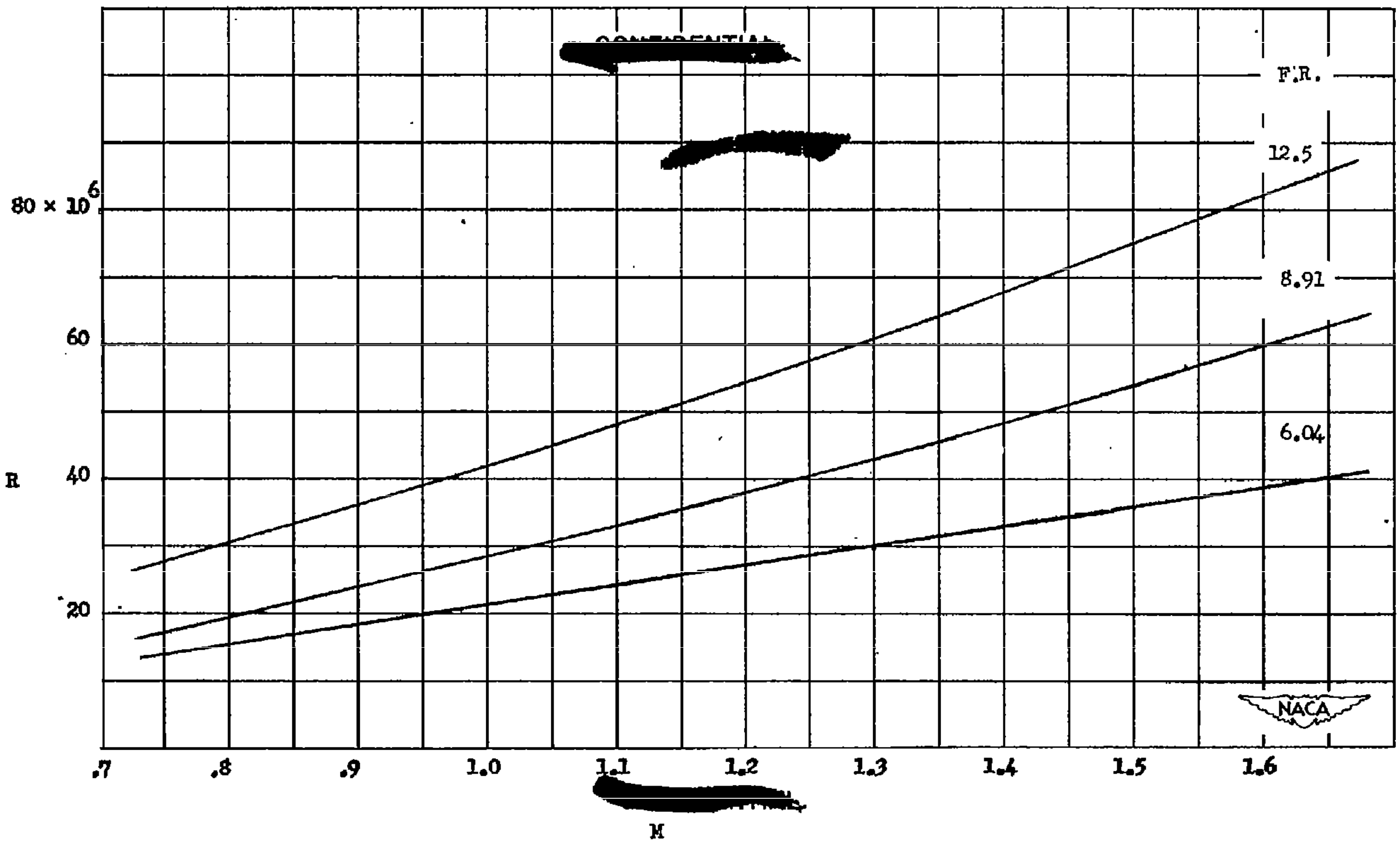
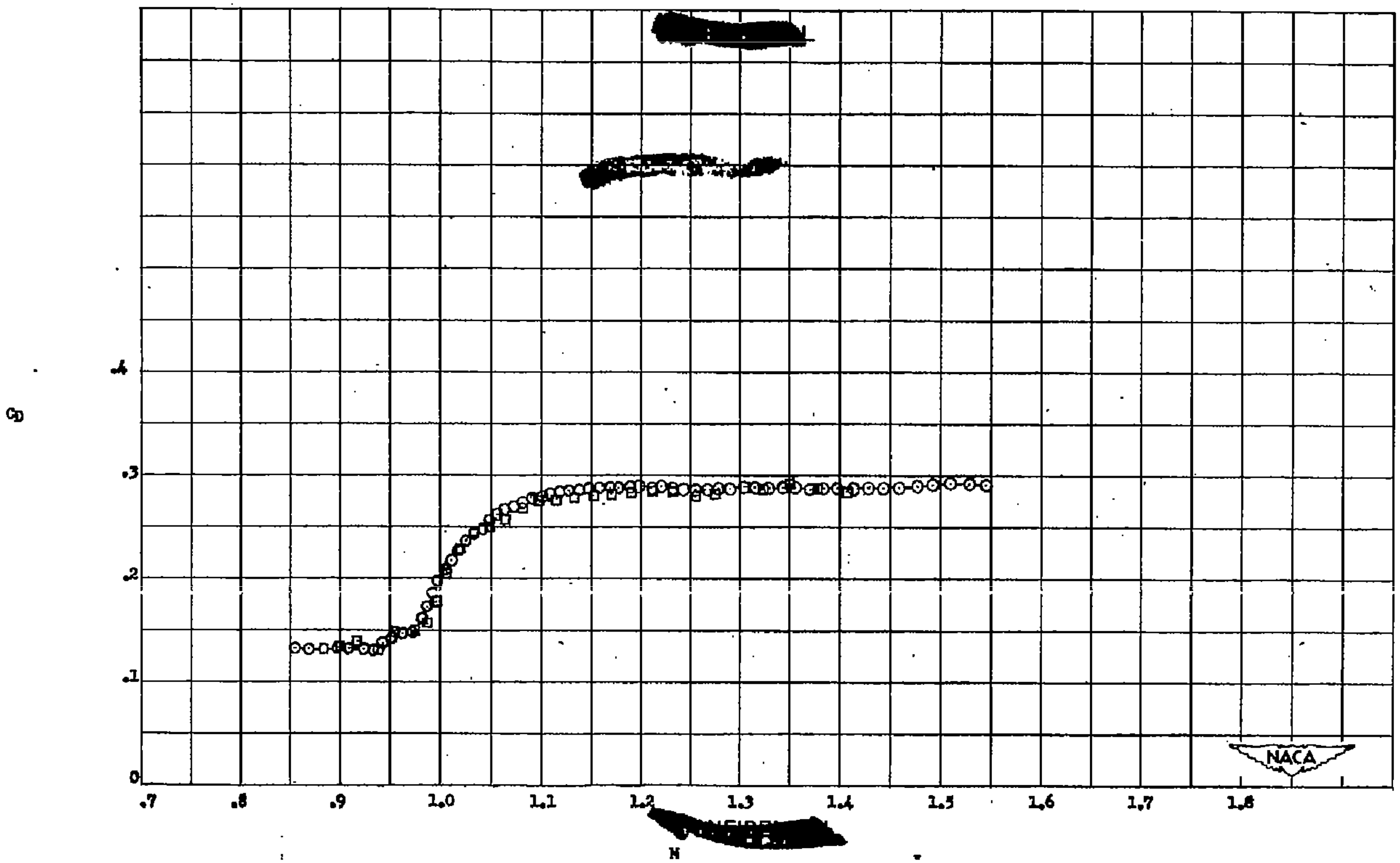


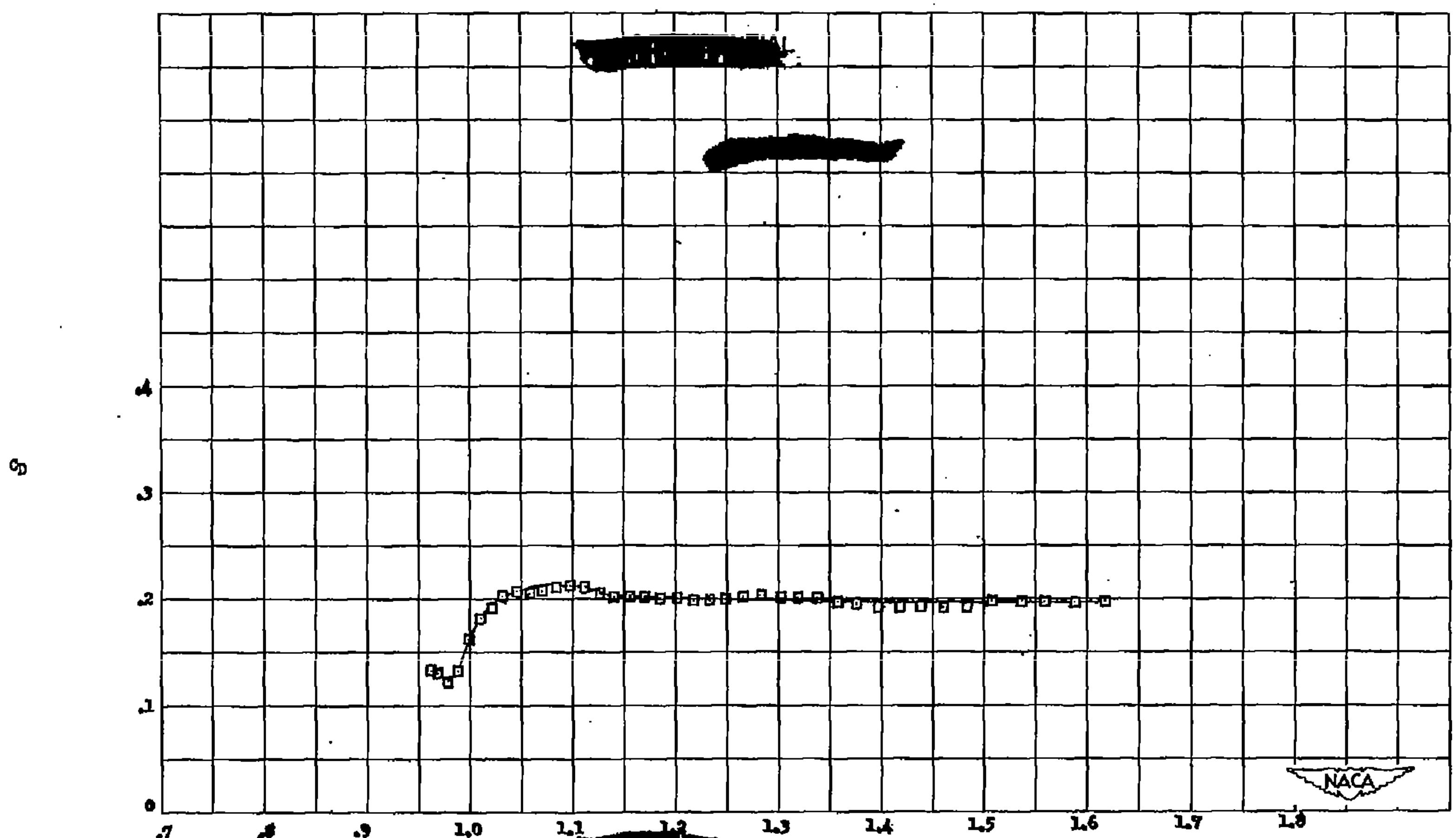
Figure 7.- Reynolds numbers based on body length against Mach number for the fineness-ratio gro[redacted].



(a) Maximum diameter at 20-percent station. Results shown for two models.

Figure 8.- Drag coefficient C_D against Mach number M for fineness-ratio-12.5 models.

[redacted]

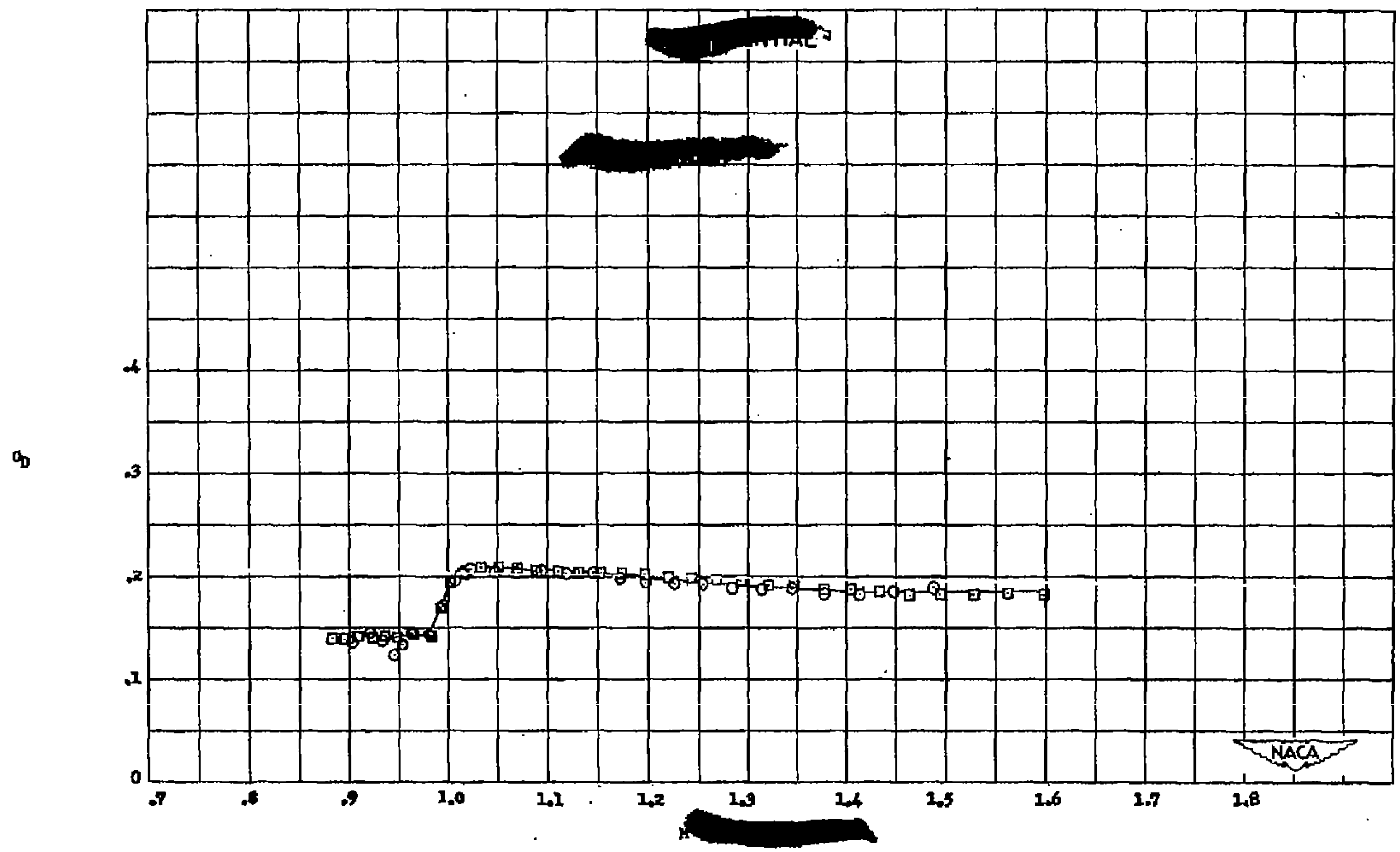


[redacted]

(b) Maximum diameter at 40-percent station. Results shown for one model.

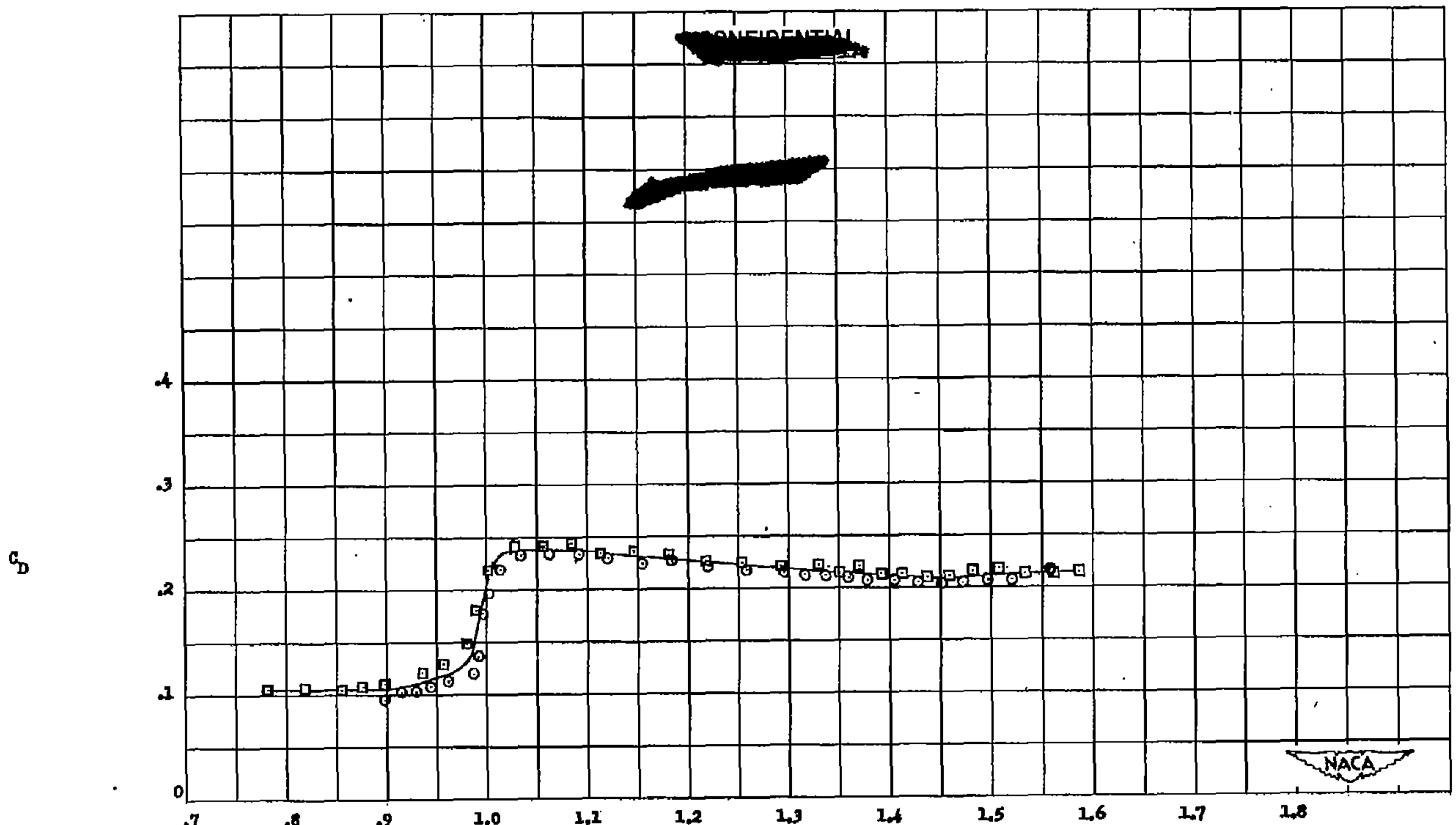
[redacted]

Figure 8.- Continued.



(c) Maximum diameter at [redacted] station. Results shown for two models.

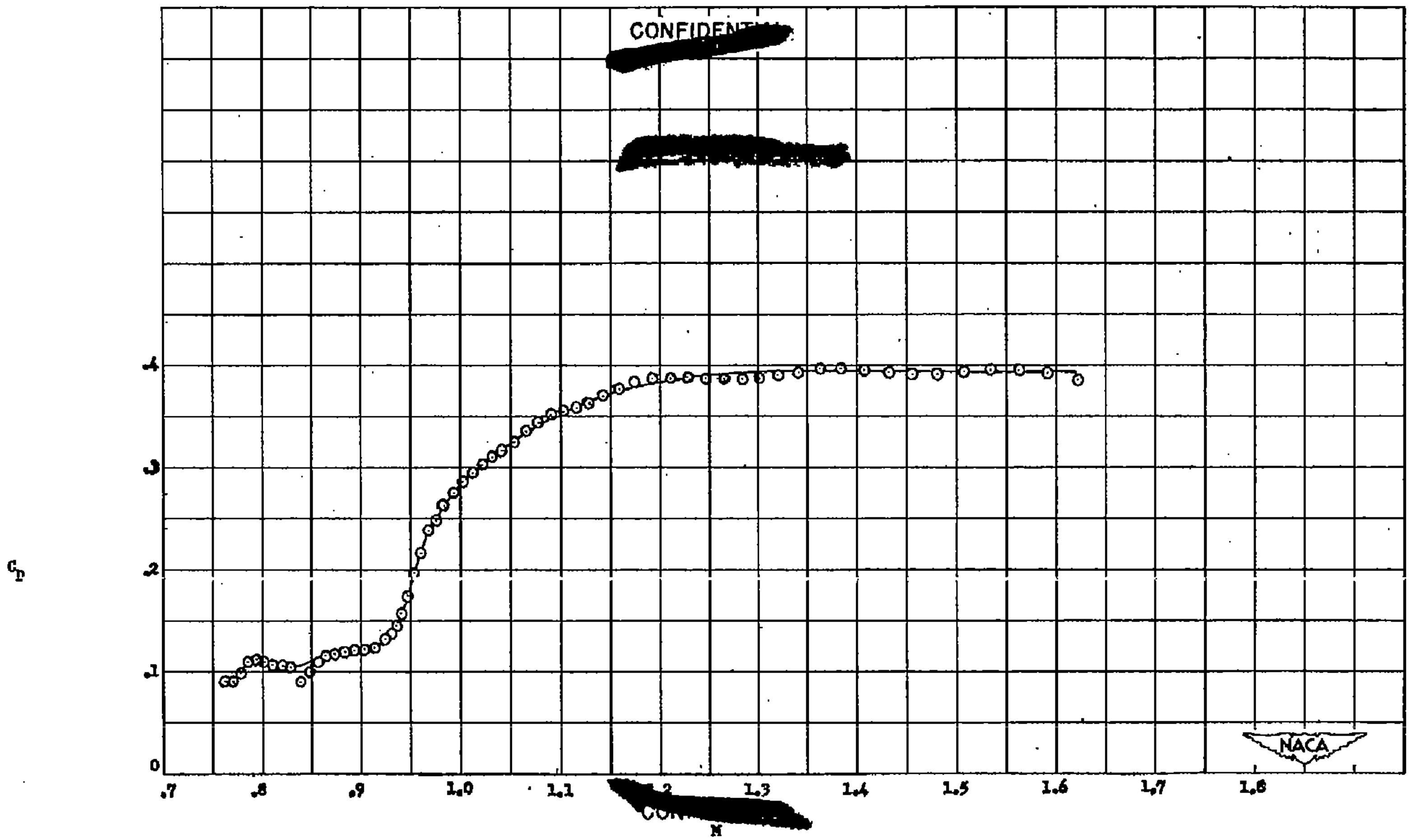
Figure 8.- Continued.



[redacted]

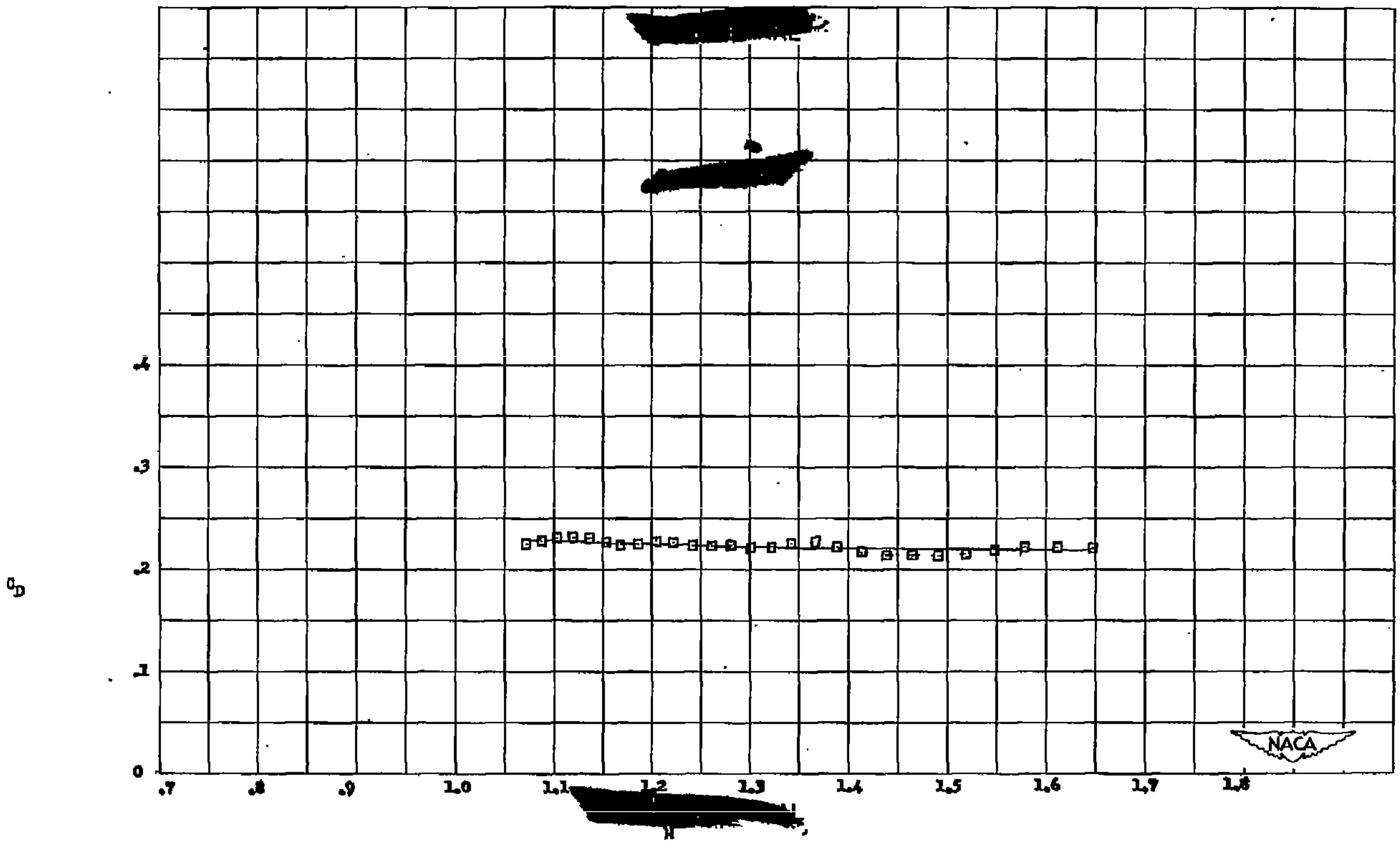
(d) Maximum diameter at 80-percent station. Results shown for two models.

Figure [redacted].- Concluded.



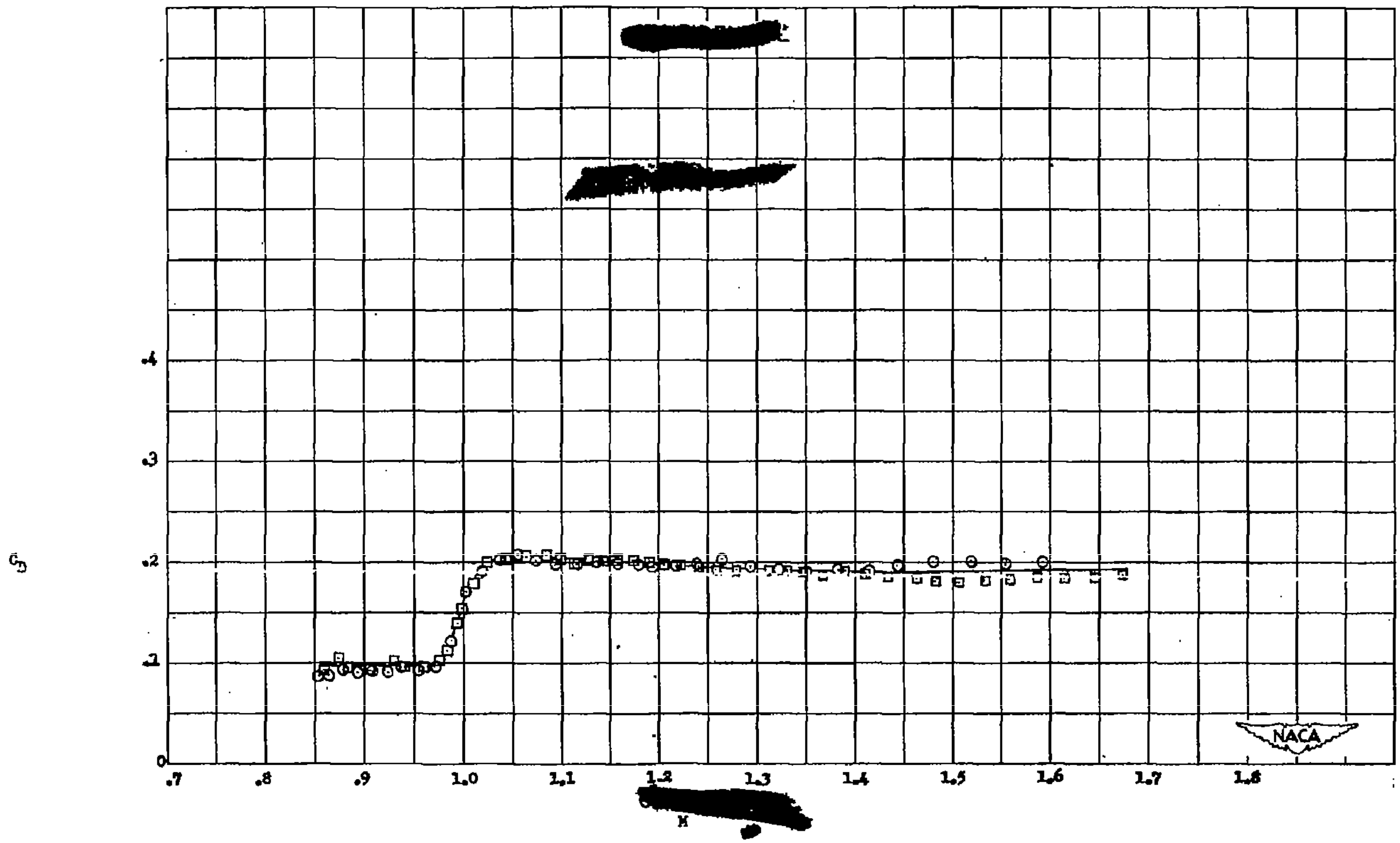
(a) Maximum diameter at 20-percent station. Results shown for one model.

Figure 9.- Drag coefficient C_D aga[redacted]mber M for fineness-ratio-8.91 models.



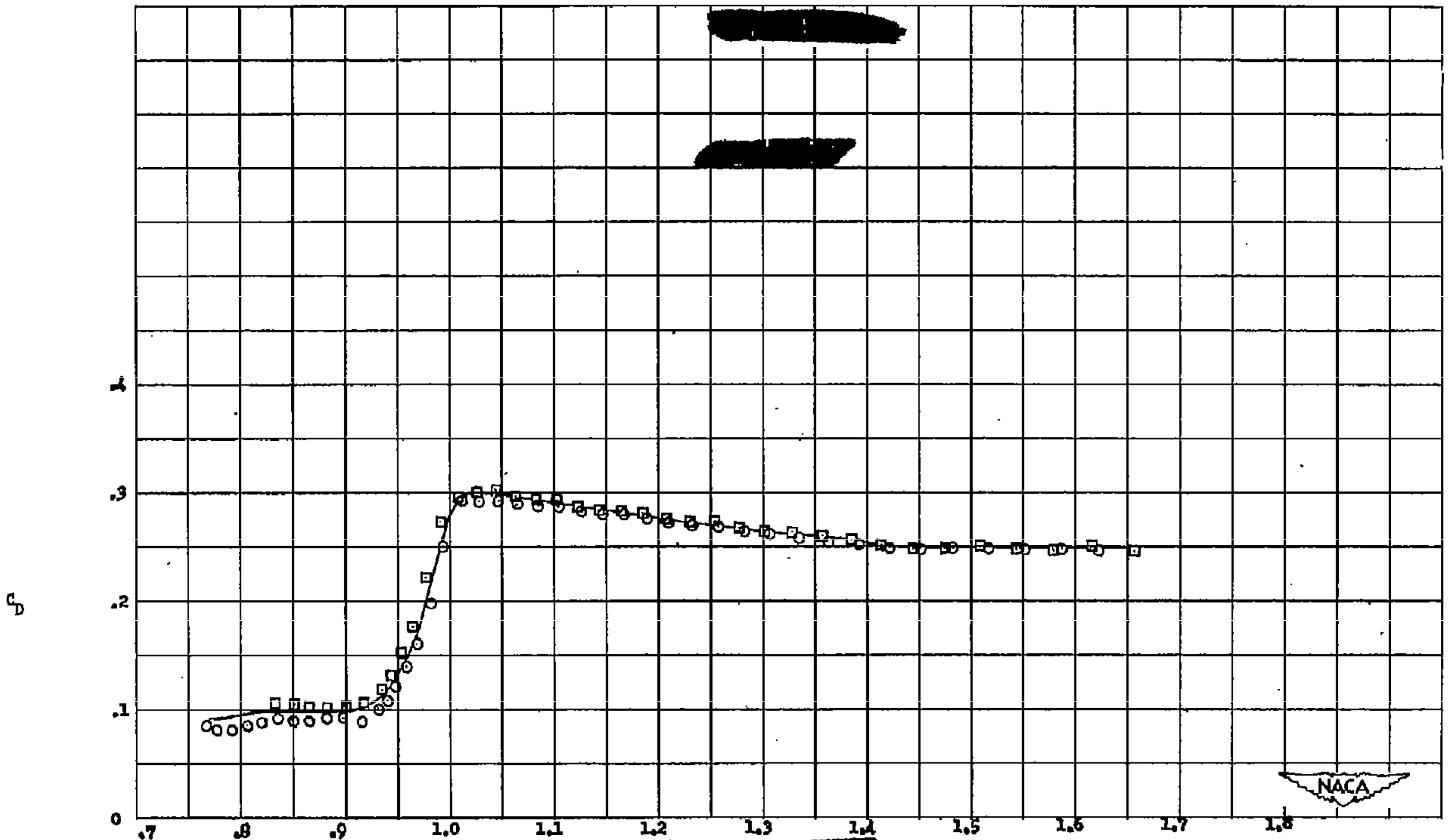
(b) Maximum diameter at 40-percent station. Results shown for one model.

Figu[redacted]nued.



(c) Maximum diameter at 60-percent station. Results shown for two models.

Fig[redacted]Continued.



[redacted]

(d) Maximum diameter at 80-percent station. Results shown for two models.

Figure [redacted]ed.

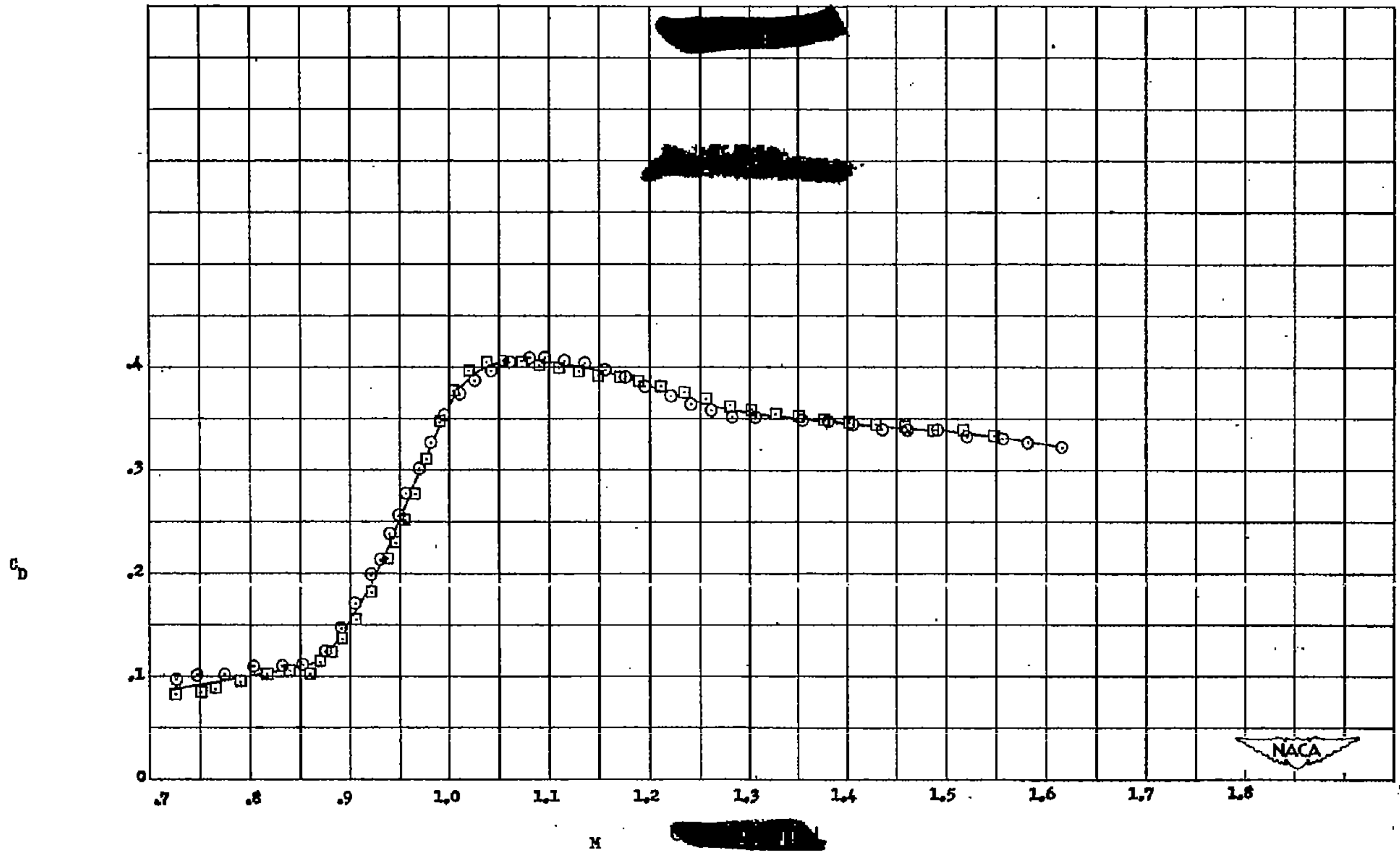
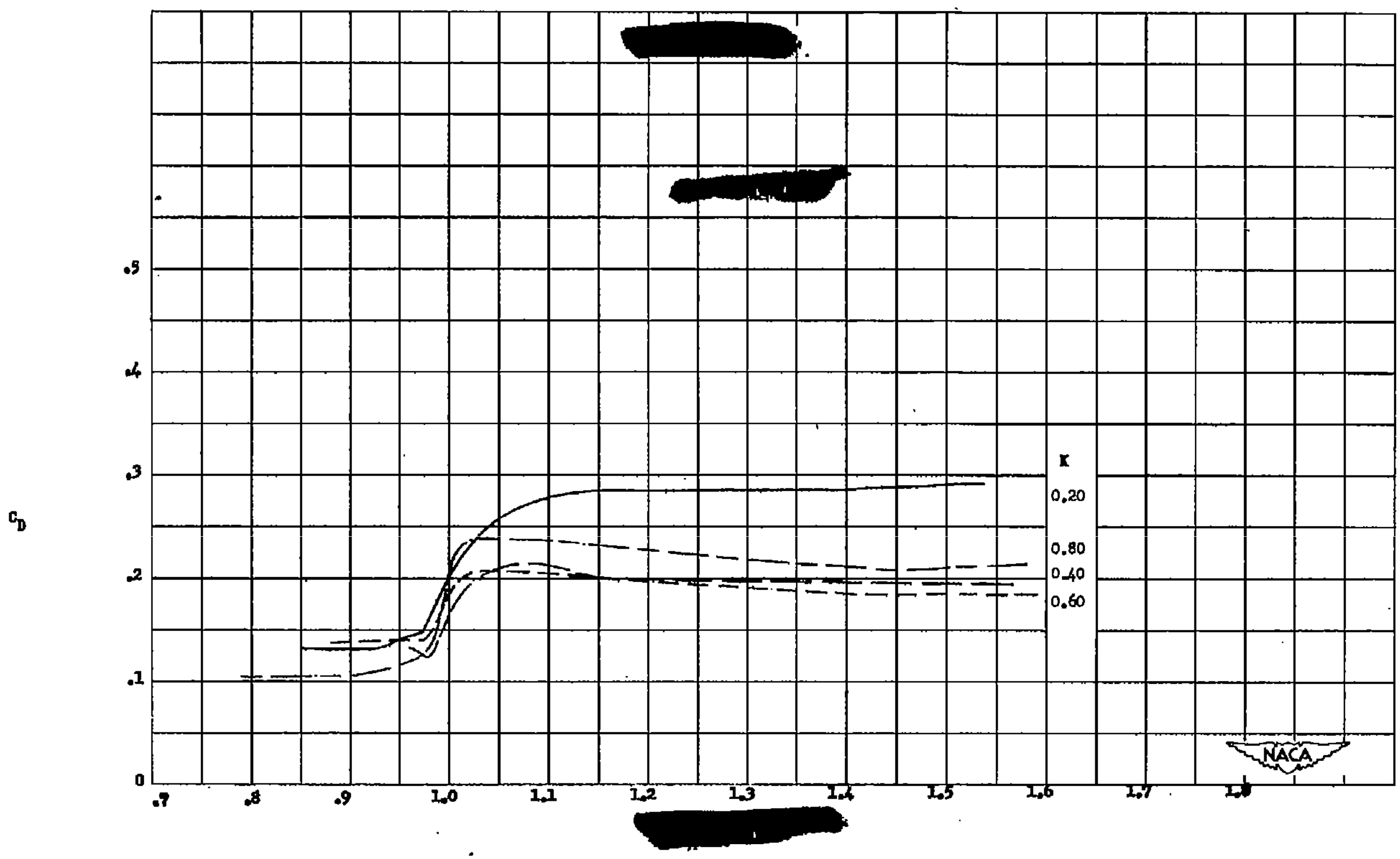


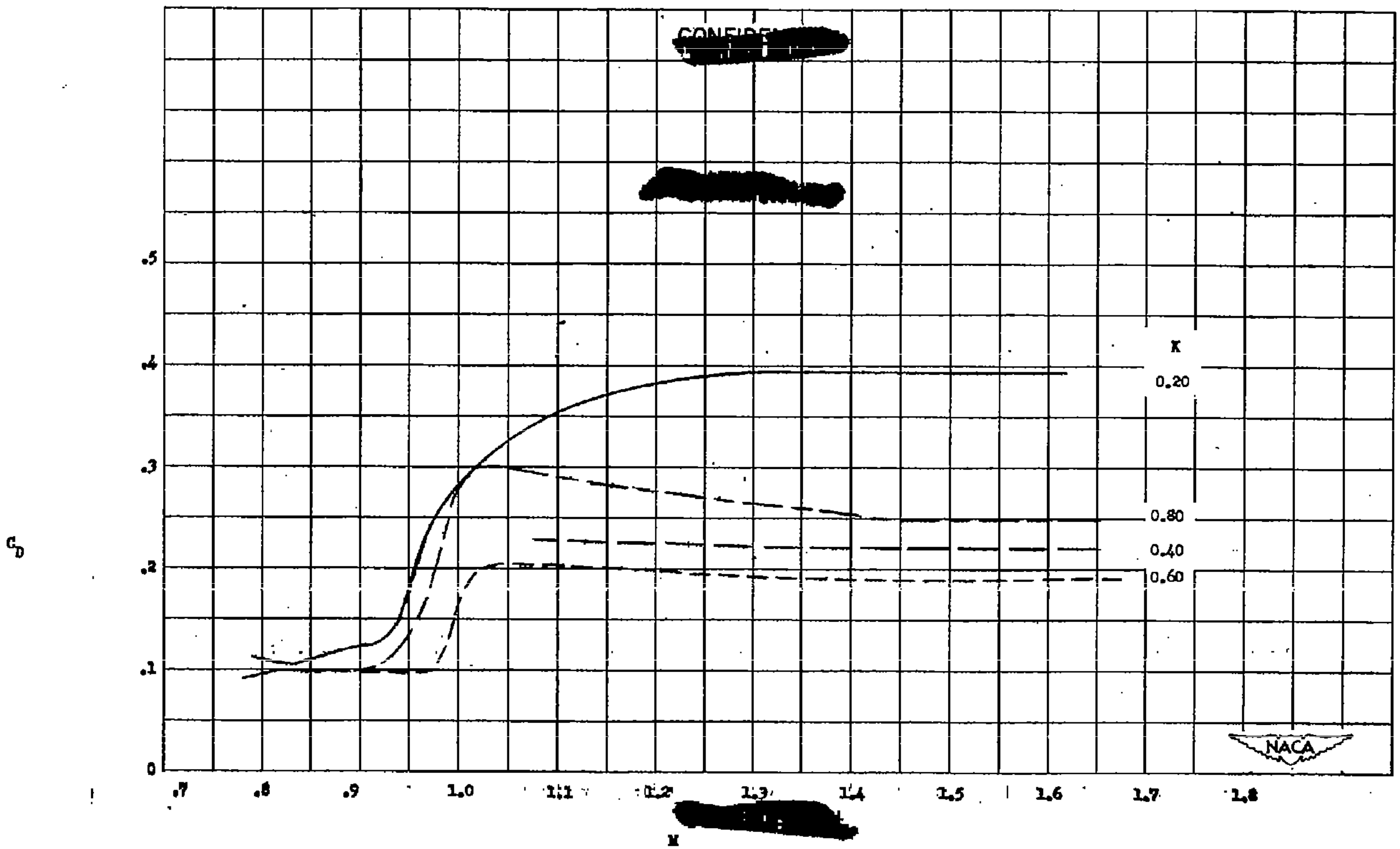
Figure 10.- Drag coefficient C_D against Mach number M for fineness-ratio-6.04 models having the maximum diameter at the 80-percent [redacted] Results shown for two models.



(a) Fineness ratio, 12.5.

Figure 11.- Drag coefficient C_D against Mach [redacted] showing effect of changing position of maximum diameter for various fineness ratios.

[redacted]



(b) Fineness ratio, 8.91.

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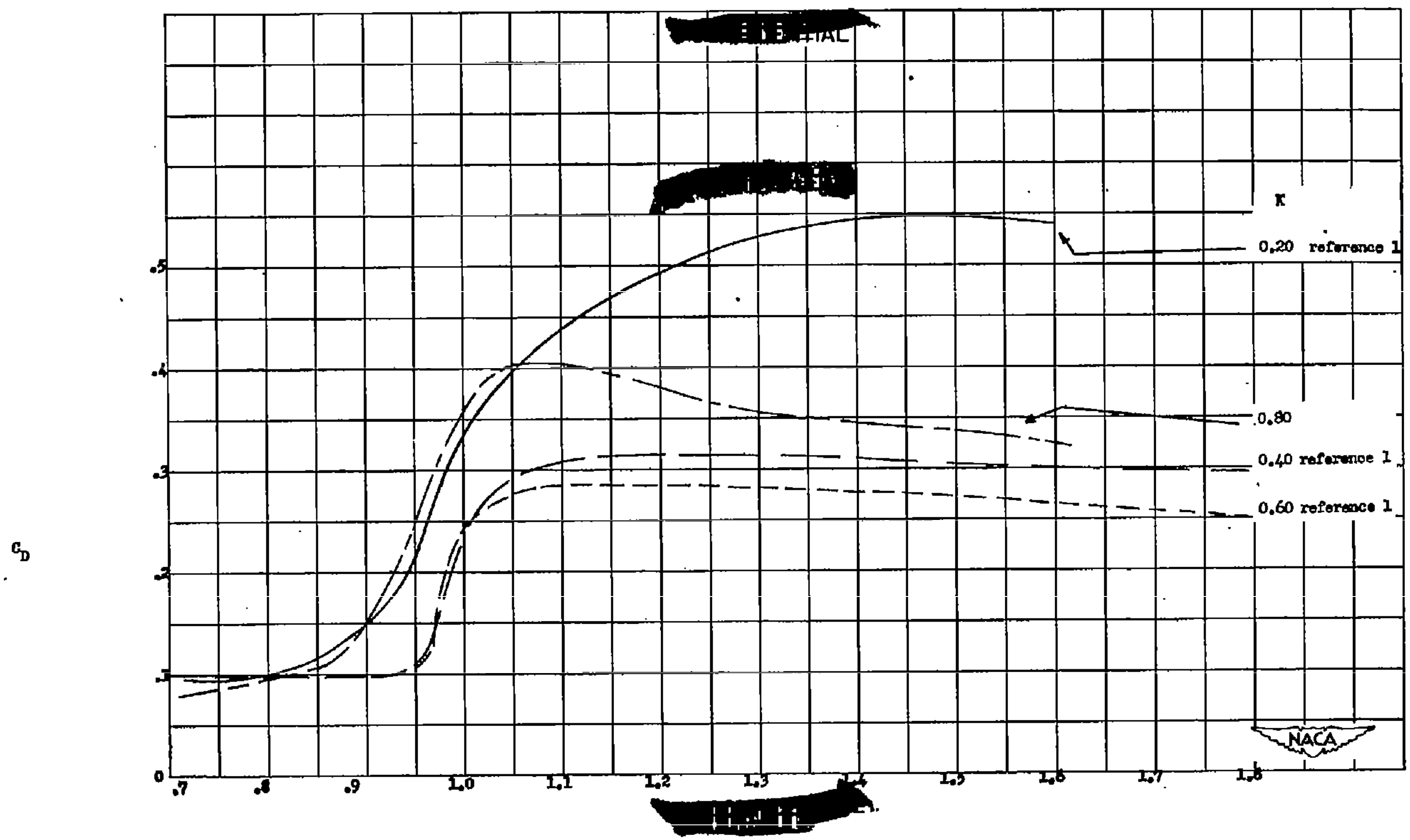

(c) Fineness ratio, 6.04.

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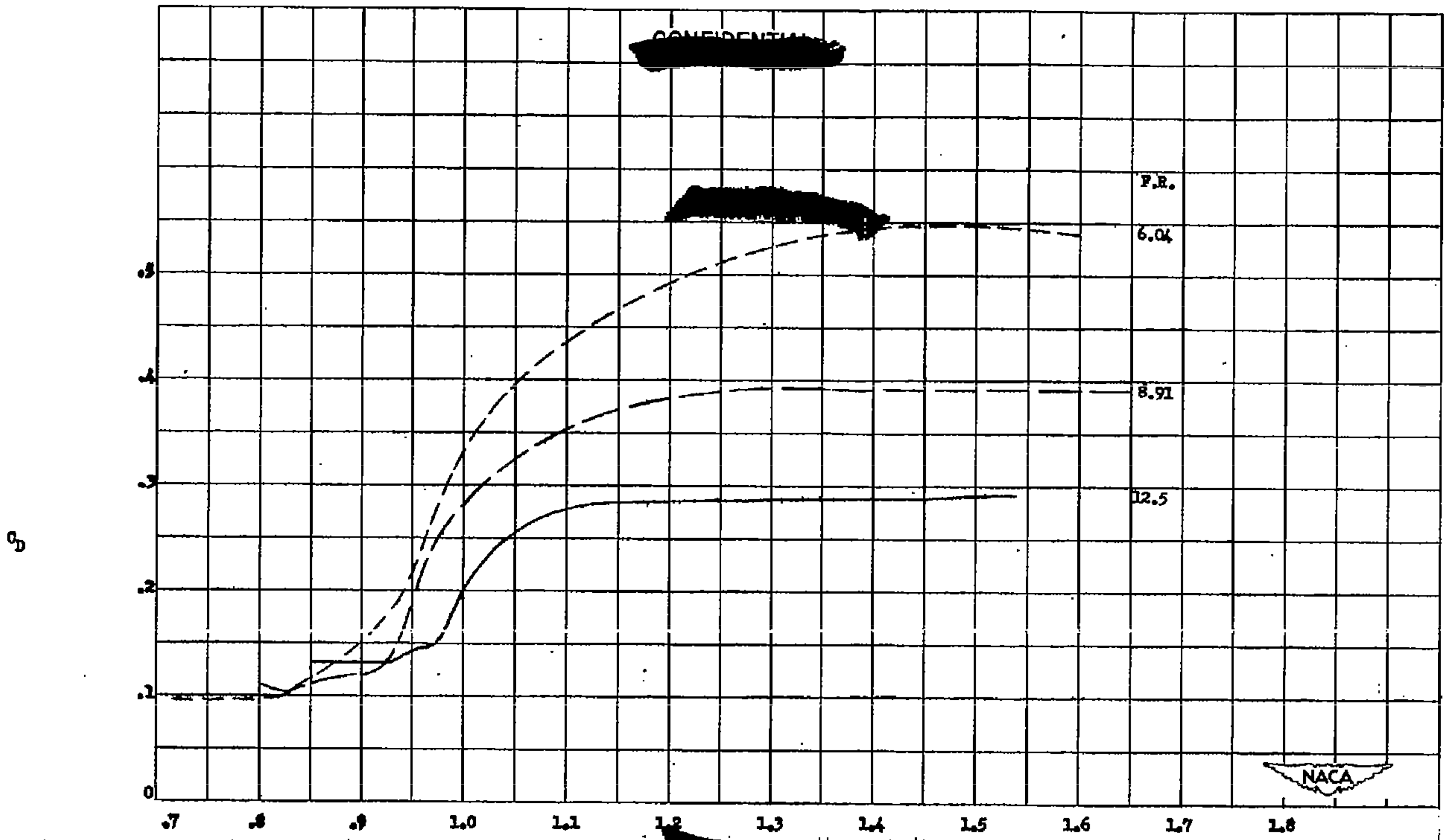

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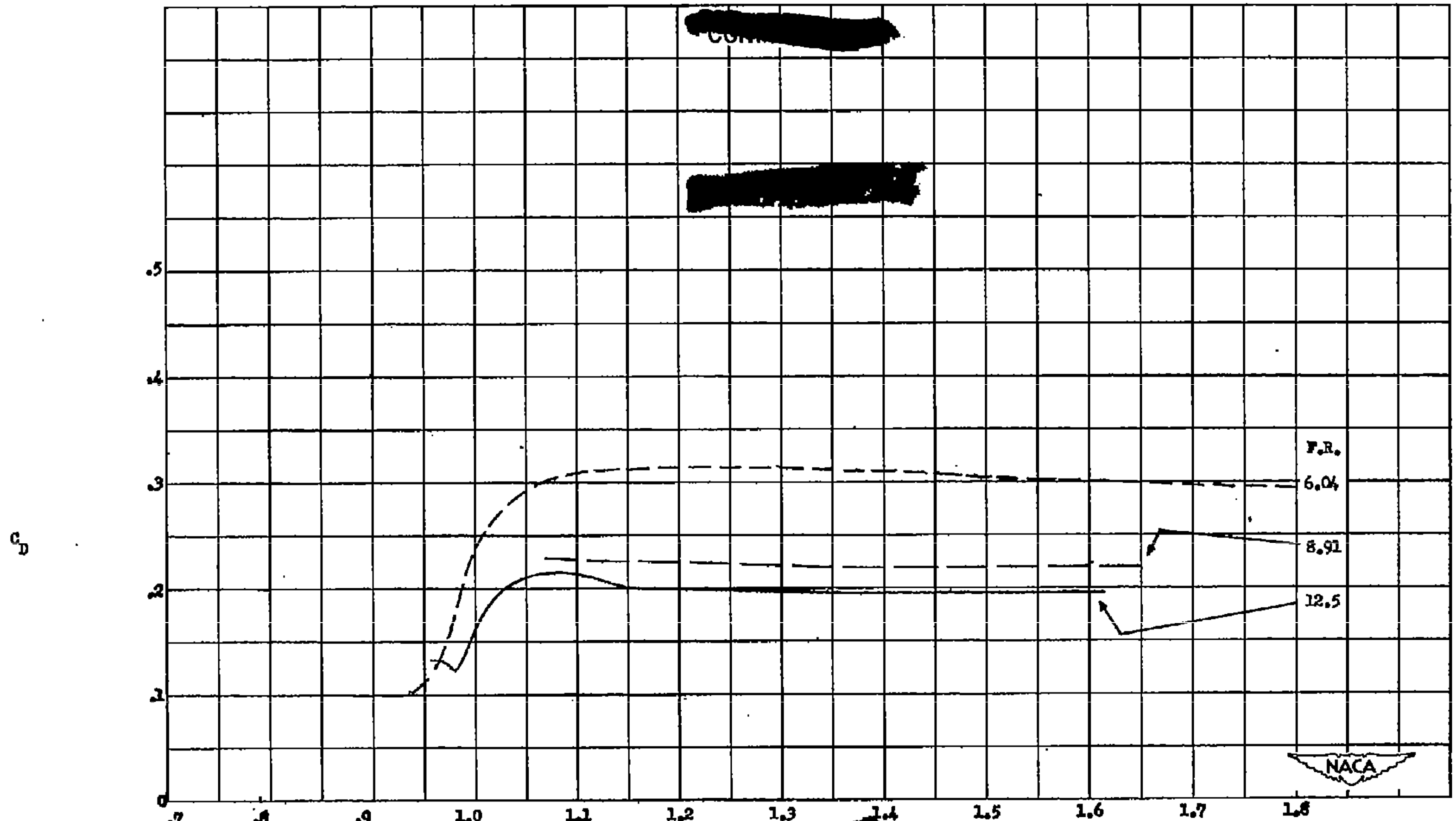
(a) Maximum diameter at 20-percent station.

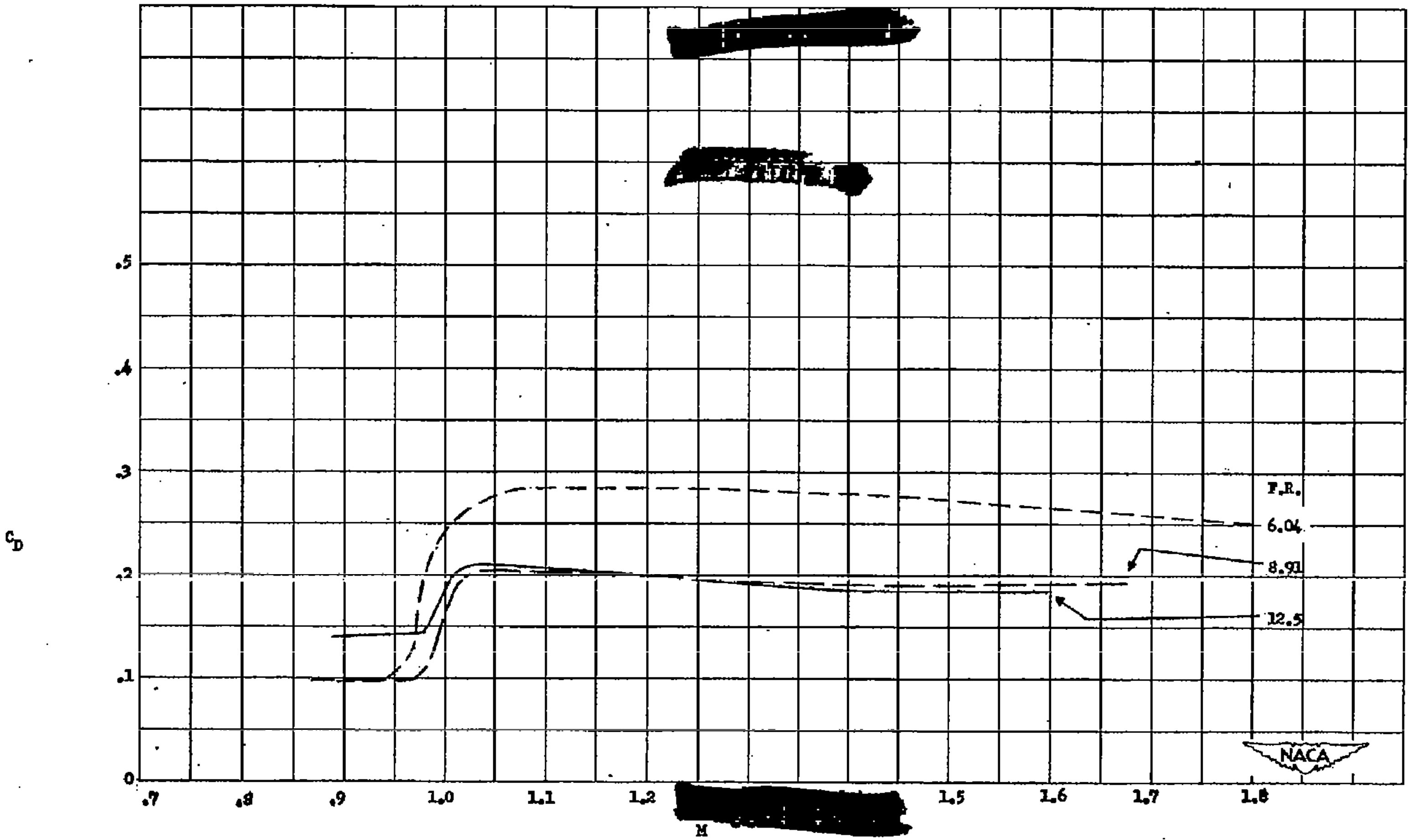
Figure 12.- Drag coefficient C_D against Mach number M showing effect of changing fineness ratio for various positio[redacted]diameter.



[redacted]

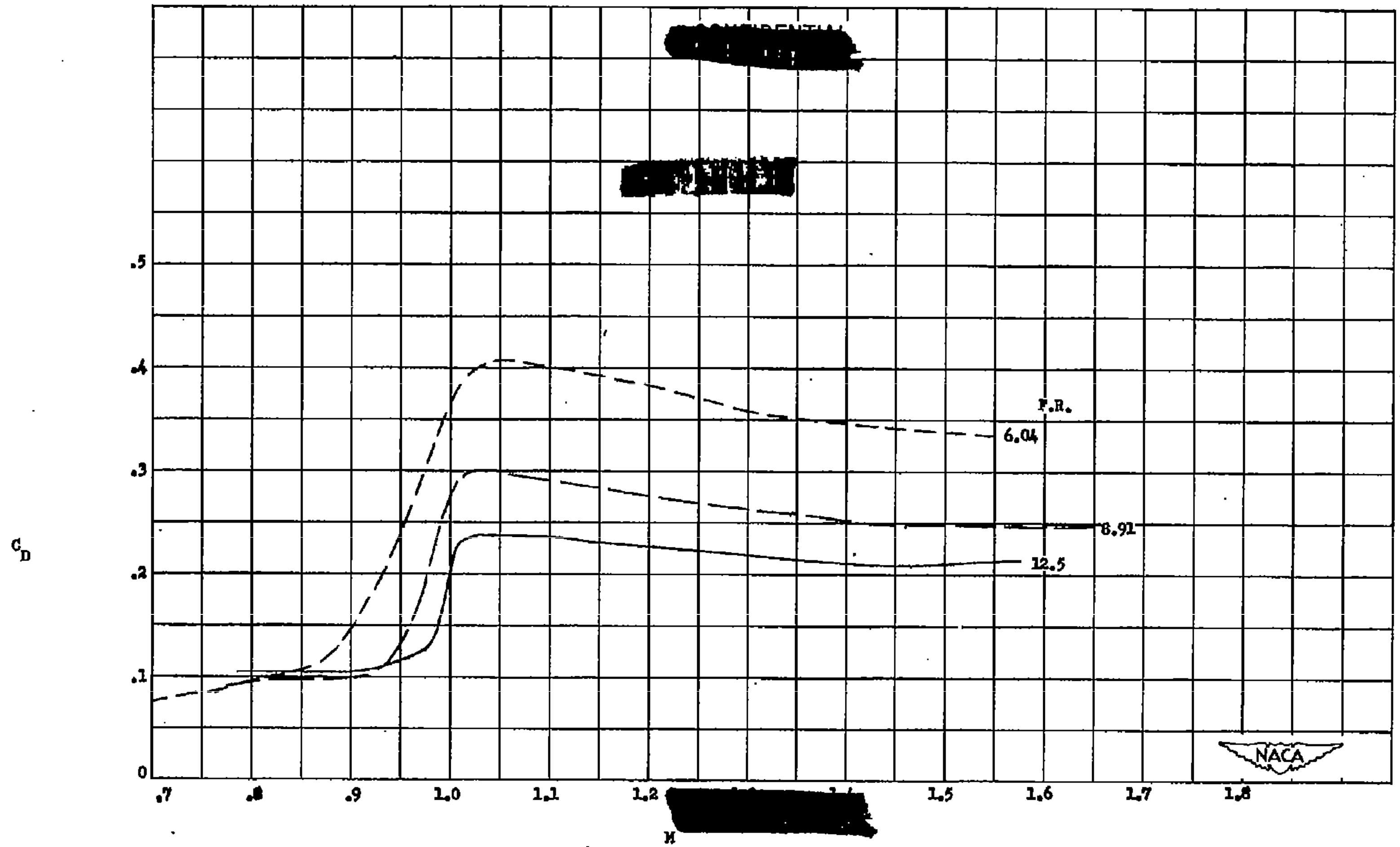
(b) Maximum diameter at 40-percent station.

Figu[redacted]



(c) Maximum diameter at 60-percent station.

Figure 12[redacted]



(d) Maximum diameter at 80-percent station.

Figu[redacted]cluded.

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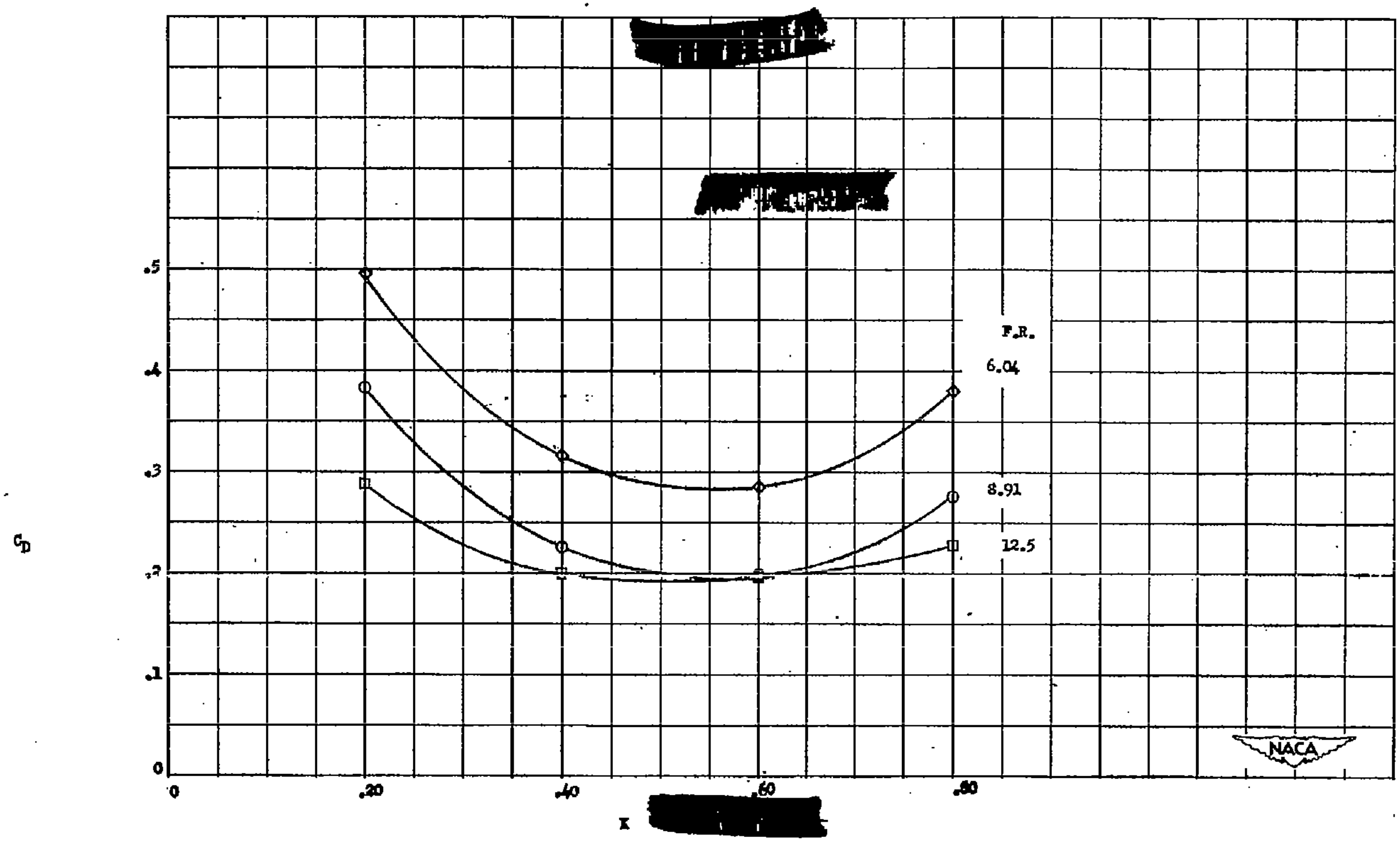
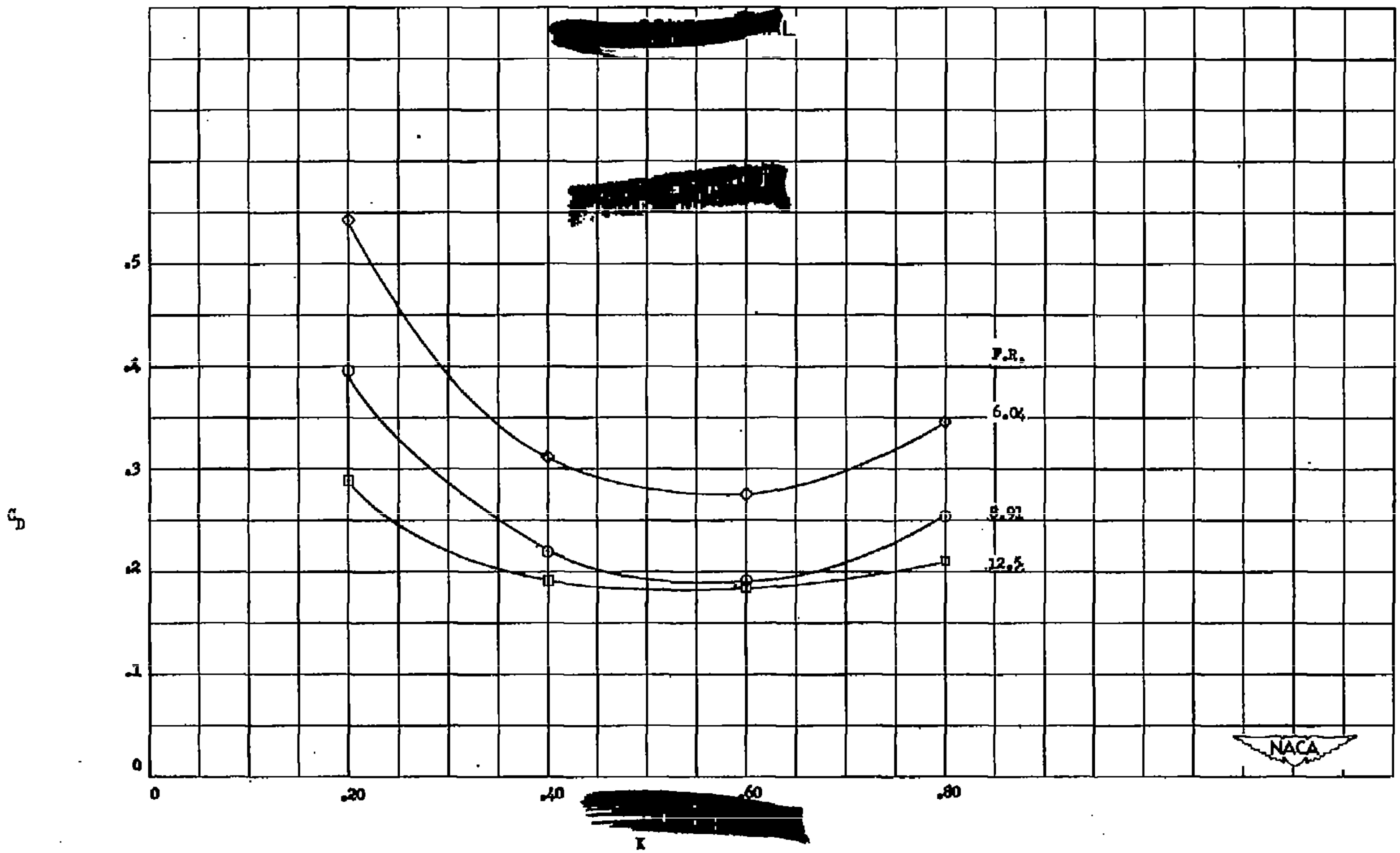


(a) Mach number = 1.20.

Figure 13.- Drag coefficient C_D against positio[redacted]iameter K for various fineness ratios.



(b) Mach number = 1.40.

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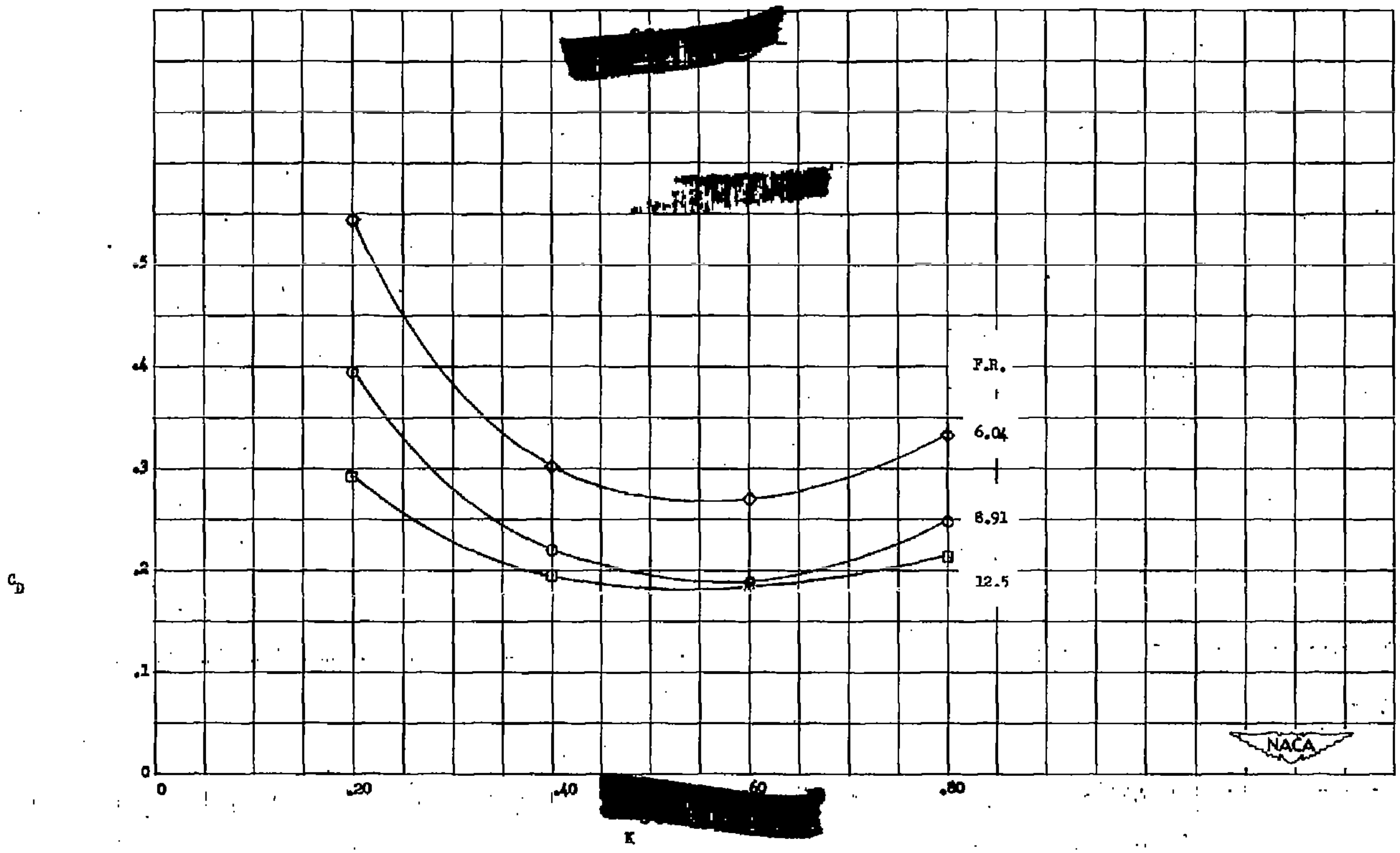

(c) Mach number = 1.55.

Fig[redacted]ncluded.

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